Experimental performance analysis on VCR diesel engine at different load conditions with varying compression ratios

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Abstract : This experiment analysis has been performed for finding the performance of an VCR diesel engine at preset load of 12kg, 80% of full load and full load conditions with varying compression ratio (CR). In this analysis, brake thermal efficiency (BTE), power produced and brake specific fuel consumption (bsfc) are observed at optimal possible compression ratio with varying load conditions. The CR and speed of the engine are varied from 12 to 18 and 1437 RPM to1450 RPM respectively at varying load. It has been observed that the BTE and brake power increases with increase in compression ratio till optimal CR 15 after that both BTE and brake power is decreased at preset load condition 12 kg whereas it has been found that bsfc (0.35 kg/KWh) is minimum at the CR 15.0. Maximum power test at different compression ratio is done at full load condition and it has been obderved that with increase in CR, speed and power increased.. Results showed improved performance of BTE and reduced SFC at optimum CR of 15 at preset load of 12kg. Performance test at 80%of full load is also performed and results are analyzed.

IndexTerms - performance, variable compression ratio,bsfc, BTE, diesel engine

1. INTRODUCTION

There has been a great deal of study on diesel-fueled engines as a result of the ever-increasing demand for petroleum-based fuels and their limited supply.Improved engine design can result in much higher combustion quality, which raises the brake thermal efficiency and reduces fuel consumption[1]. India has extremely little hydrocarbon reserves (0.4% of the world's reserve), while being blessed with renewable energy resources such as solar, wind, hydro, and bio-energy and significant coal resources. India is a net energy importer of crude oil. The majority of its energy requirements are supplied by imports, primarily in the form of crude oil and natural gas[2].The present work deals with finding the better compression ratio for the Diesel fuelled C.I engine at variable load and constant speed operation. An engine is a machine designed to convert thermal energy into mechanical energy. Variable compression ratio allows an internal combustion engine to change its compression ratio while it is running. This is done to improve fuel economy when dealing with different loads. Lower ratios are more efficient with higher loads and vice versa. The variable compression ratio could be implented in modern vehicles as per driving and load conditions to eliminate the need of turbochargers as VCR provides maximum power output at full load condition. The problem of knocking appears in turbocharged engines once boost pressure increased to a certain value so the degree of downsizing is limited. At the same time low compression ration leads to poor efficiency in low loading conditions. So VCR could meet the optimizing requirement of CRs in low as well as high loading condition hence become proper way to strengthen downsizing engines with turbocharging[3].In comparison to SI engines, diesel engines utilise VCR differently. According to Peic et al., "Variable compression ratio in diesel engines provides control of peak cylinder pressure, improves cold start ability and low load operation, enabling the multi-fuel capability, an increase in fuel economy and reduction of emissions [4].In addition, VCR permits the free use of other fuels outside petrol, such as LPG or ethanol.The secret to achieving excellent efficiency under light loads without sacrificing full load performance could be found in VCR technology. To determine optimum compression ratio through experimentation and analysis, the Computerised Variable Compression Ratio (VCR) Single Cylinder Four Stroke Diesel Engine is utilised.

2. EXPERIMENTAL SET UP AND PROCEDURE

The experimental program was carried out using a single cylinder, four stroke, air cooled, direct injection, naturally aspirated,VCR research diesel engine with a developing power of 3.5 kW at BIT Sindri ,Heat engine lab.   With the help of an eddy current dynamometer, the VCR engine was operated at different load condition with constant rpm for CR 12 to 18. The technical specifications of the engine are given in table 2.1, and the schematic diagram of the experimental arrangement is shown in fig 2.1 and fig 2.2.

Experimental procedure: The variable compression ratio engine is started using diesel, and load is set to zero while changing the compression ratio manually once it reaches stable operating conditions at a constant compression ratio load is increased to 12 kg and the experiment is performed and observation is recorded on IC engine software . constant water supply is provided through the engine rotameter at 150 l/s, while the calorimeter rotameter is set to 75l/s. The tests are run continuously at 1437-1450 rpm. At various compression ratios of 12-16, all the performance parameters, like Indicated Power (IP), Specific Fuel Consumption (SFC), Brake Thermal Efficiency, Indicated Thermal Efficiency and Mechanical Efficiency are calculated.

Table 2.1: Engine specifications.

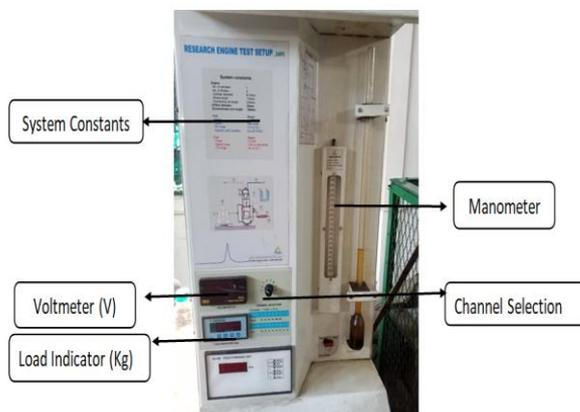| Engine	Diesel
Numberofstroke	4
Numberofcylinders	One
Bore	87.5 mm
Strokelength	110 mm
Connectingrodlength	234 mm
Orificediameter	20 mm
Dynamometererarm length	185 mm
Cooling	Watercooling
Compressionratio	12:1 to 18:1
Ratedpower	3.5KW@ 1500 rpm
Typeofdynamometer	Eddycurrentdynamometer
Softwareused	ICEngineSoft

Fig 2.1: Details of Single cylinder 4 stroke diesel engine test setup

Fig 2.2: Single cylinder 4 stroke diesel engine test setup

3. PERFORMANCE CALCULATION:

Indicated thermal efficiency (η_t): Indicated thermal efficiency is the ratio of energy in the indicated power to the fuel energy.

$$\eta_t = \frac{IndicatedPower}{FuelEnergy}$$

$$\eta_t = \frac{IndicatedPower(KW) * 3600}{FuelFlow\left(\frac{Kg}{Hr}\right) * CalorificValue\left(\frac{KJ}{kg}\right)}$$

Brake thermal efficiency (η_{bth}): A measure of overall efficiency of the engineis given by the brake thermal efficiency. Brake thermal efficiency is the ratio of energy in the brake power to the fuel energy.

$$\eta_{bth} = \frac{BrakePower}{FuelEnergy}$$

$$\eta_{bth} = \frac{BrakePower(KW) * 3600}{FuelFlow\left(\frac{Kg}{Hr}\right) * CalorificValue\left(\frac{KJ}{kg}\right)}$$

Mechanical efficiency (η_m): Mechanical efficiency is the ratio of brake horse power (delivered power) to the indicated horsepower (power provided to the piston).

$$\eta_m = \frac{brakePower}{IndicatedPower}$$

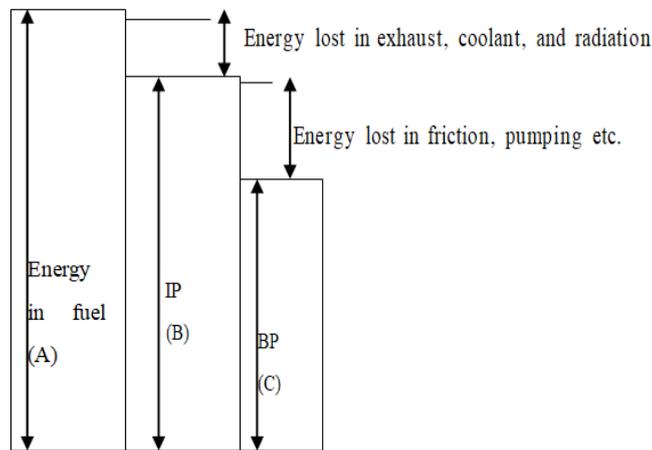Frictional power = Indicated power – Brake power

Fig 3.1 Energy breakdown of fuel

Indicated thermal efficiency = B/A
Brake thermal efficiency = C/A
Mechanical efficiency = C/B

Volumetric efficiency (η_v): The engine output is limited by the maximum amount of air that can be taken in during the suction stroke, because only a certain amount of fuel can be burned effectively with a given quantity of air. Volumetric efficiency is an indication of the 'breathing' ability of the engine and is defined as the ratio of the air actually induced at ambient conditions to the swept volume of the engine. In practice the engine does not induce a complete cylinder full of air on each stroke, and it is convenient to define volumetric efficiency as:

$$\eta_V = \frac{\text{Mass of air consumed}}{\text{mass of flow of air to fill swept volume at atm conditions}}$$

Brake power (kw):

$$BP = \frac{2\pi NT}{60000} = \frac{2\pi N(W \times R)}{60000}$$
$$= \frac{0.785 \times RPM \times (W \times 9.81) \times Armlength}{60000}$$

Brake specific fuel consumption (Kg/kwh):

$$BSFC = \frac{Fuelflow(kg/hr)}{BP(kw)}$$

4. RESULTS AND DISCUSSIONS

Tests were conducted at compression ratios of 12 to 18 at a constant speed of 1450 rpm. The graphs below show fuel consumption (Kg/Hr) vs. compression ratio (fig 4.1.1) and BTE vs compression ratio(fig4.1.2) as performance characteristics parameters. Specific fuel consumption (SFC), brake thermal efficiency, mechanical efficiency, and indicated power (IP) are among the characteristics that are determined.

4.1 Engine performance at different compression ratios at preset load of 12kg

Table 4.1 Result calculation obtain by IC engine software at preset load

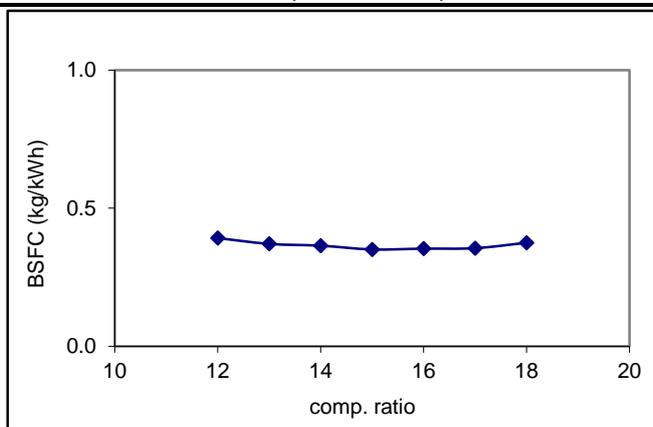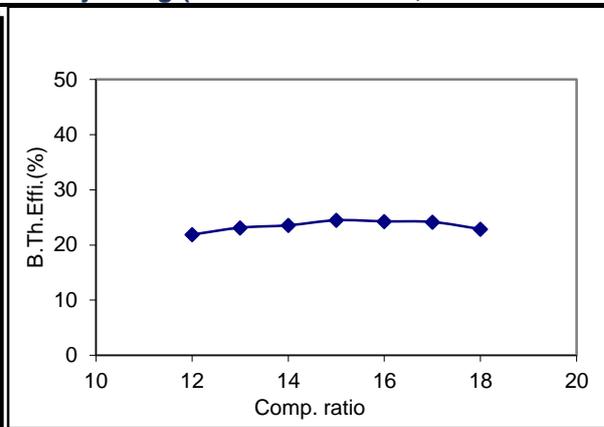| Comp ratio	BP (kW)	BSFC (Kg/kWh)	BTh.eff. (%)	A/Fratio	Vol eff (%)
18	3.29	0.37	22.86	20.74	76.65
17	3.31	0.35	24.15	21.96	76.84
16	3.30	0.35	24.27	22.45	78.15
15	3.30	0.35	24.46	22.62	78.10
14	3.30	0.36	23.55	21.95	78.75
13	3.30	0.37	23.11	21.56	78.81
12	3.28	0.39	21.86	20.52	79.30

fig 4.1.1 BSFC vs Comp ratio graph

fig4.1.2 Brake thermal efficiency Vs Comp ratio graph

Effects of VCR on specific fuel consumption

Brake-specific fuel consumption is inversely proportional to the thermal efficiency of an engine which is controlled by changing compression ratios. As CR rises, efficiency also rises, cutting down on fuel usage. According to (Hariram & Vagesh Shangar 2015), their VCR CI engine's BSFC decreased by around 30% when CR was raised from 16 to 18, while BTE improved by 13% at full load when CR was increased. In the present study we observed compression ratio (CR) is varied from 12 to 18at speed of around1450 RPM at constant load of 12kg. The brake thermal efficiency increases with compression ratio till optimum CR 15 then again decreases. Similarly brake power increases and decreases in same manner. The BSFC decreases with CR till optimum value of 0.35 kg/KWh at CR of 15-17 then increased.

4.2Max Power test at different compression ratios at full load

Table 4.2 Result calculation obtain by IC engine software at full load

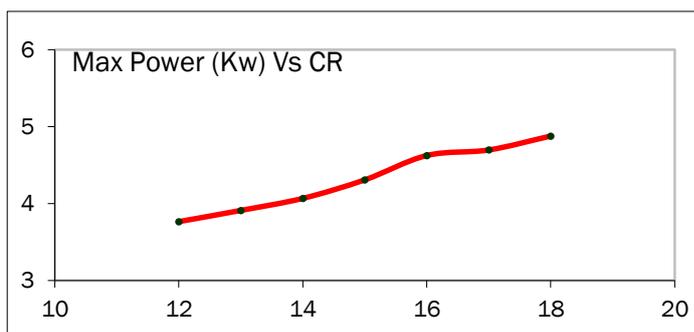| CR	Full load (kg)	RPM	Power(kw)
12	18	1100	3.76
13	18.2	1130	3.91
14	18.6	1150	4.07
15	19.2	1180	4.31
16	19	1280	4.62
17	19	1300	4.69
18	19	1350	4.88

Fig. 4.2.1 Max Power (Kw) Vs Comp ratio graph

Maximum power test at different compression ratio is done at full load condition and it is observed that with increase in Compression ratios, power output increases linearly(fig 4.2.1).

4.3 BSFC and Brake thermal efficiency test at @ 80% load at different compression ratios

Table 4.3 Result calculation obtain by IC engine software at 80% load

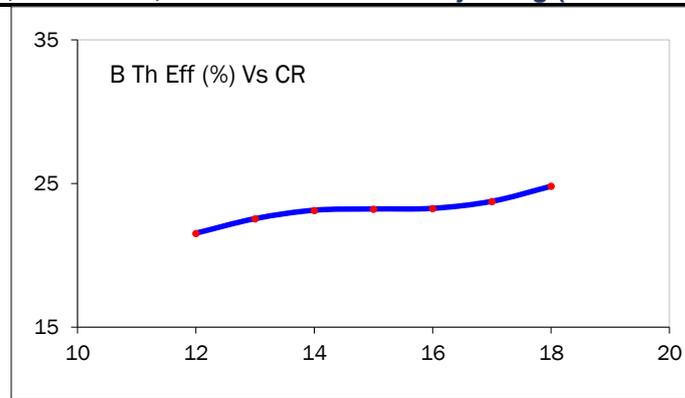| CR	Speed RPM	Load Kg	BSFC kg/kwh	B th eff %
12	1430	13.6	0.40	21.54
13	1426	14.1	0.38	22.55
14	1436	13.9	0.37	23.14
15	1436	13.9	0.37	23.23
16	1426	15	0.37	23.27
17	1424	15.3	0.36	23.76
18	1435	14.9	0.35	24.81

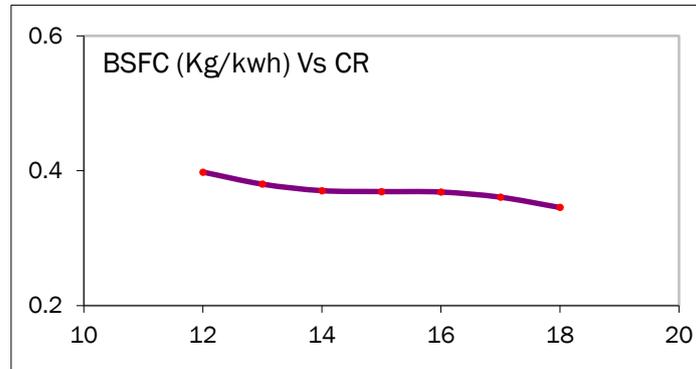Fig 4.3.1 Brake thermal efficiency Vs Comp ratio graph

Fig 4.3.2 BSFC vs Comp ratio graph

Performance parameters were analyzed at 80 % of full load at different CRs and results showed that Brake thermal efficiency increases with compression ratio as shown in fig 4.3.1, whereas brake specific fuel consumption decreases with increase in compression ratio. So at 80% load BSFC curve seems promising as it decreases with compression ratio as shown in fig 4.3.2.

5. CONCLUSION

The compression ratio in VCR engines can be changed according to the load conditions, which has an impact on the efficiency of the diesel cycle. The experiments were done on the C. I engine with diesel at various compression ratios leads to the following conclusion. At preset load of 12 kg the brake thermal efficiency increases with compression ratio till optimum CR 15 then again decreases. Similarly brake power increases and decreases in same manner. The BSFC decreases with CR till optimum value of 0.35 kg/KWh at CR of 15 then increased.

So for the given engine, a compression ratio of 15 is found to be optimum at preset load of 12kg. At a compression ratio of 15, better fuel economy is attained. Lower compression ratios result in increased fuel usage. Increased brake thermal efficiency, decreased brake specific fuel consumption (BSFC), and increased heat release rate are observed with an increase in compression ratios particularly at higher loads.

6. REFERENCES

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